Hydrodynamics and morphology of filamentous bacteria in a stirred tank fermenter

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ABSTRACT

Besides the positive effects of stirring (i.e., improvement of the mass, heat and momentum transfer), the induced turbulence may alter the microbial activity. Hydrodynamic stress is the generic term used to describe the unfavourable effects of the turbulence on the microorganisms. In order to contribute to a better knowledge of this complex phenomenon, we have studied the influence that mixing conditions may have on a filamentous bacterium: Actinomadura R39.

Investigations are carried out in a 5 l batch fermenter operated at different stirring speeds and with two different types of impellers, known to produce different flow pattern within the fermenter: Rushton turbines (radial flow) and intermittent axial-radial flow.

The influence of hydrodynamics on Actinomadura R39 is quantified by the evolution of its morphology, estimated by image analysis. The hydrodynamics in the fermenter is characterised using an artificial broth which has the same rheological properties than the fermentation broth, by the tracer methodology and power measurements. Tracer experiments are used to determine the mixing time and to represent the mixing flow pattern in the stirred tank by a compartmentalized model.

Relationships can be established between morphological modifications and hydrodynamic parameters characterizing the flow in the fermenter. Scale-up rules depend on the type of morphological parameter considered. The existence of such correlations between model parameters and the morphology also validates the physical significance of the compartmentalized model.

COMPARTMENTALIZED MODEL

- 8 compartments
- 2 parameters: the pumping flow between the compartments (p (m³/s))
- the diameter of the mobile zone dz (m)

HYDRODYNAMICS

MIXING TIME

- Rushton Turbines : Np = 15.3 (± 0.3)
- Intermig : Np = 2.3 (± 0.1)

POWERS

- Npg Rushton Turbines
- Npg Intermig

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MORPHOLOGY ANALYSIS

- Area: 0.04 (N²) ± 0.01
- Shape Factor = -2.4 (N²) + 102
- Area = -3.9 (N²) + 102
- Shape Factor = -2.4 (N²) + 102

SOURCES

- Pellets area (mm²)
- Impeller diameter (m)
- Maximum Feret diameter (mm)
- Minimum Feret diameter (mm)
- Diameter of mobile zone (m)
- Flow parameter (m³/s)
- Flow parameter (with gas 5.1/min (m³/s))
- Power number (n² N/min)
- Power (W)
- Crotch perimeter (mm)
- Peripheral tip speed (m/s)
- Mixing time (s)
- Density (kg/m³)

CONCLUSIONS

The area and the Feret diameters (minimum and maximum) are correlated to N²P, corresponding to the ratio NpNp. Those quantities are global characteristics of hydrodynamics of the fermenter. The relation to the ratio NpNp indicates that not only the power input is a factor but also the way the impeller dissipates it into the bulk. Rushton turbines are high power number mobiles (Np=15.3) and Intermig are low power number impellers (Np~2.3). The shape factor is correlated to the impeller tip speed N, to the power input P, and to d. Those quantities are local characteristics of hydrodynamics of the fermenter (i.e., maximum shear stress). The ratio of the minimum and maximum Feret diameters is constant and independent of the cultivation conditions. It is equal to 0.59. The density of holes (i.e., the number of holes per mm²) is also important of the cultivation conditions. It is about 5500 holes/mm². Those correlations developed in this work are relevant for two different kind of impellers (Rushton turbines and Intermig) producing clearly different flow patterns.

Beyond results related to a specific strain: Actinomadura R39, this work proposes a general methodology to study the influence of mixing conditions on the morphology of filamentous bacteria. This morphology reflects the complex and multiscale influence of hydrodynamics: the microbial strain integrates during its growth spatial and temporal fluctuations of the hydrodynamic conditions encountered in the bulk of the fermenter. This work validates the relevance of the physical significance of compartmentalized models to describe the mixing flow within a stirred tank fermenter.